§24. Development of Three-dimensional MHD Simulation Code and Studies of Kinetic Effects in Geomagnetic Disturbance

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We are developing three-dimensional (3D) magneto-hydrodynamical (MHD) - Adapted Mesh Refinement (AMR) simulation code. The AMR technique adapts dynamically the grids to suit the physical conditions and can monitor running structures by fine grids, so this is appropriate for simulating dynamical motion of localized structure in evolved global structure. We adopted Roe method, one of TVD method, for a flux part in order to capture discontinuities without artificial numerical viscosity in hydrodynamical (HD) simulation code and checked that code by reproducing a one-dimensional (1D) shock tube problem and a 3D Sedov solution. When we extended it to be able to solve MHD equations, it was found that whether the code could calculate the expected results depended on models. In order to find out causes of the problems and to make our code suitable for an extension in future, we performed the test simulations using three methods for the flux part. We prepared include files corresponding to Lax, Roe and Roe-MUSCL method so that three methods can be available by switching those files in our code. A MHD shock tube problem was tested in a simulation box 1x1/32x1/32 with grid sizes 1/256 – 1/1024 which means level 8 – 10. Figures 1-6 are simulation results.: the pair of Figs. 1 and 4, Figs. 2 and 5,

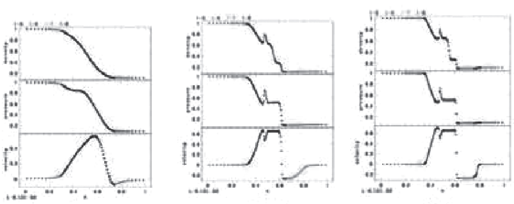

Fig.1 Fig.2 Fig.3

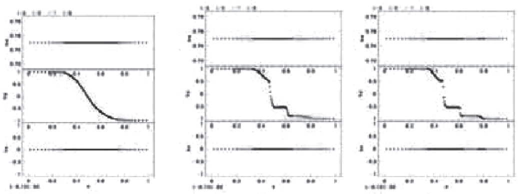

Fig.4 Fig.5 Fig.6

and Figs.3 and 6 are calculated by Lax, Roe and Roe-MUSCL method respectively. Density (upper panel), pressure (middle) and velocity (lower panel) are presented in Figs. 1-3, and the x -(upper panel), y-(middle), z-component (lower panel) of magnetic field are shown in Figs. 4-6. It is seen that Lax method failed in capturing shock structure, and that Roe-MUSCL method was successful in expressing sharp discontinuities. We found that numerical oscillation occurred in a magnetic field component which should be constant, when the further high resolution simulation with level 10-12 (1/1024-1/4048) was performed. Moreover, it is confirmed that we could obtain expected results in any methods with the uniform grid. We could not resolve the problem yet, however, we could develop a function of switching a flux solver, which is expected to be useful for rapid improvement of our code.

It is considered that magnetic reconnection is correlated to substorm, but their relation is not clear yet. In our real-time numerical simulator for the solar wind-space-magnetosphere-ionosphere coupling system, adopting the 3D MHD simulation code developed by Tanaka, it can be seen that the Earth's magnetosphere changes dynamically is response to the solar wind conditions, e.g., that substorm occurs frequently even if the solar wind conditions are not so severe. In order to investigate relation of magnetic reconnection and substorm or role of magnetic reconnection in the Earth's magnetosphere, multi-scale approach should be considered. For the first step, we studied the solar wind conditions for occurrence of substorms. Figure 7 shows clear ejection of a plasmoid which was a result of magnetic reconnection. Sudden change from north to south in the z-component of the magnetic field in the solar wind is necessary, and non-zero y-component of that is also important. We improve this code at present so that it can treat data obtained by the other MHD code which simulates phenomena in the region including reconnection points to interact the kinetic data.

Fig. 7